

Reply

Predicted Environmental Impact and Expected Occurrence of Actual Environmental Impact

Part II: Spatial Differentiation in Life Cycle Assessment via the Site-Dependent Characterisation of Environmental Impact from Emissions by José Potting & Michael Hauschild
Int. J. LCA 2 (4) 209-216 (1997)

The Structure of Impact Assessment

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We have read with interest the letter from HEIJUNGS and WEGENER SLEESWIJK (previous pages) about our framework for site-dependent characterisation in LCA (POTTING and HAUSCHILD, 1997a). We are pleased to see clear convergence in thinking, and feel no unbridgeable differences between our framework and the adapted one, brought forward by HEIJUNGS and WEGENER SLEESWIJK. We suspect these differences to go back to a slightly different rationale behind both proposals and to a slightly different use of terminology. HEIJUNGS and WEGENER SLEESWIJK distinguish three dimensions (fate, intake, effect) as relevant for characterisation. Their dimensions seem to be based on the causality chain. Our dimensions cover also the causality chain, but are rather based on informations relating to the three central objects in this chain:

1. Effect or hazard dimension, covering information about the intrinsic substance characteristics.
2. Fate or source dimension, covering source related information about emission characteristics and distribution/dispersion parameters from initial to final compartment(s).
3. Target dimension, covering information about the target system regarding the exposure situation (background concentration, population density etc.) and the sensitivity of the target system.

An example:

The number of hydrogen ions which an emitted substance can theoretically release, gives us the acidifying potential of an emission per functional unit. However, this intrinsic substance characteristic is insufficient to tell much about the fate of that emission in the environment. We have to include

information about emission and dispersion/distribution characteristics to estimate, for instance, that only 4% of an NO_x emission in The Netherlands deposits on The Netherlands itself, while the remainder travels up to 1000 km before it deposits. (BARRET et al., 1996). The fate or source potential informs us about the concentration/deposition increase per functional unit at the location of a target system. However, it does not tell anything about the background concentration/deposition being in force at the target locations (full concentration = background concentration + concentration increase). After all, 82% of total NO_x deposition on The Netherlands is imported from neighbouring regions (BARRET et al., 1996). Nor does the fate potential tell us anything about the target's capacity to cope with this concentration/deposition increase. We thus have to look to the target system itself to get informed about:

- (1) the capacity to remove nitrogen by uptake or denitrification,
- (2) the ability of soils to neutralise acidifying depositions,
- (3) the extent to which the capacity for uptake, denitrification and neutralisation is already used by the background depositions of nitrogen, sulphur etc.

We recently established equivalency factors (covering all the effect/fate/target information mentioned above) that in a very simple way relate emission quantities to their acidifying impact on the receiving target system. The acidification factors are calculated for 44 European regions with help of the integrated assessment model RAINS. Only the region of emission is needed as additional input information from inventory analysis to assess the acidifying impact from an emission on its deposition area (POTTING et al., 1998).

In LCA, we deal for the larger part with non-local impact types with general features similar to acidification. Typical for these impact categories is that (POTTING *et al.*, 1997b)¹:

- The emission from an individual source is received by many target systems over a large area of several hundreds to thousand kilometres (multiple target systems).
- One target system receives contributions from many sources (multiple sources).

Extension from the usual effect/fate modelling to effect/fate/target modelling in LCA thus introduces a considerable demand of additional input information to calculate equivalency factors for Life Cycle Impact Assessment¹.

We preferred to follow as closely as possible the existing terminology in our framework in order to avoid unnecessary confusion. Unfortunately, this terminology seems to create such confusion. The label "effect" is somewhat misleading, since it is associated with the type of effect information as we know traditionally from human and eco-toxicity information: a no-effect-level based on some laboratory species. However, such no-effect-level refers primarily to the intrinsic hazard ability of the substance (based on laboratory tests only), and does hardly give any information about the specific characteristics of target species outside in the real world. Nevertheless, HEIJUNGS and WEGENER SLEESWIJK rightly point out that it is somewhat confusing and suggesting overlap to use the term "no-effect-level" in both effect and target dimension. It is maybe more correct to rename the "effect dimensions" into "substance dimension" and to avoid the term "no-effect-level" in relation to target information in Figure 2 in our framework-article (POTTING and HAUSCHILD, 1997a).

To complicate the issue, HEIJUNGS and WEGENER SLEESWIJK have a point in their identified overlap between our substance and target informations. Target modelling uses of course also substance specific toxicity characteristics, if it aims to construct a target specific NEL. In that case, the intrinsic substance toxicity information is replaced by target specific toxicity information per substance. As a matter of fact, fate modelling also relies on intrinsic substance charac-

teristics like persistency, lipophilicity or molecular weight. Here, the relevant substance specific information is replaced by fate specific information per substance. Do we have a problem now?

The hazard potential of a large group of chemicals (all chemicals labelled with the risk phrase R53 according to the EU environmental hazard classification criteria) is expressed exclusively by their lack of biodegradability and their bioaccumulating potential (PETERSON *et al.*, 1994). This makes fate then to a subscript of effect in the framework of HEIJUNGS and WEGENER SLEESWIJK (assuming that they see biodegradability and bioaccumulation as part of the fate dimension; they do not specify fate). Intake through ingestion is taken into account already in the air quality guidelines of the WHO (WHO, 1987), which makes intake to a subscript of effect in the framework of HEIJUNGS and WEGENER SLEESWIJK. More of such examples can be found, also taken from their own letter, where fate, intake and effect can be written as sub- or superscripts from each other.

HEIJUNGS and WEGENER SLEESWIJK define independence between dimensions by the fact that it is not possible to write any of them as a sub- or superscript of the other dimensions. The fact that their own framework is liable to the problem that they exactly identify in our proposed framework does of course not affect the relevancy of their point. But as HEIJUNGS and WEGENER SLEESWIJK already state themselves, the reasons to qualify some things as parameters and other things as subscripts in their framework is more a practical than a fundamental one. The same applies for representing parameters independently as dimensions, or within the brackets or parenthesis of another parameter. That depends to a high degree on the chosen definition of the impact category and/or way of modelling this impact category. For example, the equivalency factors for human and eco-toxicity of GUINÉE *et al.* (1996) integrate intrinsic substance toxicity, as well as several fate and exposure informations, as well as informations about the intakes from human beings all in one and the same equivalency factor. Also the acidification factors from POTTING *et al.* (1998) cover several types of informations. PLEIJEL *et al.* (not published) on the other hand designed site-factors for acidification that cover only fate and exposure aspects, and have to be multiplied separately with the potential of substances to release hydrogen ions.

A framework is a framework and intends nothing else than to provide a structure for something that may also be structured in another way. Especially generic frameworks have the tendency to become somewhat artificial and need to be slightly restructured when applied on specific impact categories. The sense of a framework is in the first place provided, however, by the line of thinking it expresses. Though based on slightly different rationalities, our framework and the one suggested by HEIJUNGS and WEGENER SLEESWIJK are quite close in this respect. Hopefully we can move the discussion to the actual elaboration of the framework into feasible characterisation modelling in LCA.

¹ This results from the fact that non-local impacts are caused by substances with relative long lifetimes. These substances therefore disperse over considerable distances. As a result, the full emission from an individual source contributes only marginally to exposure of the receiving target systems (POTTING *et al.*, 1997b). If the full emission from an individual source contributes marginally, consequently also the emission related to one functional unit from that source contributes marginally. Marginality means linearity and/or proportionality, and this provides meaningful use of equivalency factors for impact assessment in LCA! For the non-local problems, integrated assessment models can be used to establish equivalency factors that cover all effect/fate/target information mentioned above and that relate in a very simple way emission quantities to their impact on the receiving target system. The global warming potentials and ozone depletion potentials already used in many LCAs are established with such models, and we recently calculated such equivalency factors for acidification with the integrated assessment model RAINS (POTTING *et al.*, 1998).

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Book Reviews

Environmental Assessment of Products

Volume 1: Methodology, Tools, and Case Studies in Product

Authors: Henrik Wenzel, Michael Hauschild, Leo Alting
 Publisher: Chapman & Hall, Kluwer Academic Publishers
 ISBN 0-412-80800-5, U.S. \$ 150,- (85 GBP)

It is exciting to see such a thorough text on Life Cycle Assessment. This book will steadily replace the early, more qualitative and conceptual SETAC text as the best explanation of life cycle techniques. The origins of this book are in the commitment by Danish industry and Environmental Protection Agency to encourage, with substantial resources, the use of life cycle for improvement of manufacturing and products. The magnitude of this commitment is impressive and is reflected in the material available to the reader of this book. A major benefit of this book is the education of professionals and students to life cycle principles and tools. However, a number of the figures, tables, and examples are of such good quality that these will be of immediate use to those currently involved with life cycle technology.

The organization of the book centers on three areas,

- 1) need and use of life cycle evaluations
- 2) methods and techniques
- 3) detailed examples of life cycle uses.

For the first area, the authors present a series of forces that are driving the expansion of life cycle applications. The historical summary is an important contribution of this book, describing the multiple legislative and environmental management systems that potentially influence industry to take a more unified approach. Clear information is given on the models of industrial systems and the flow of material, energy, and processes over a cradle-to-grave boundary. The authors achieve a world perspective in the development of life cycle and in the impacts that are described by the multi-national manufacturing system.

The methodology used in this book follows the classical three tier life cycle approach. However, in-depth applications have been used to significantly expand the content and to explain the subtleties involved in inventory, assessment, and decision-making. Since the authors have also developed extensive life cycle software, the progression of the book chapters has a very clear structure. The book information is generally more assessment than inventory.

The third area is examples and these are very rich in information and insight. The five examples are generally complex products, such as a refrigerator. Each begins with description and market context leading into the cradle-to-grave life cycle. The assessment allows determination of areas with the greatest influence. The authors are careful to identify what information is missing and often why. The decision-making aspects demonstrate the capability of life cycle to find pollution prevention options. It is of particular interest that the authors can integrate results into marketing, long-term corporate objectives, and the actual product development cycle.

In summary this book is excellent and is highly recommended to those in the manufacturing field. It really clarifies current and future implications of environmental issues on products and manufacturing. This book has an important role in the fields of industrial and chemical engineering, management, university education regarding life cycle, and sustainability.

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